A Synthesis of Oceanic Time Series from the Chukchi and Beaufort Seas and the Arctic Ocean, with Application to Shelf-Basin Exchange

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LONG TERM GOALS

My long-term goals are to understand the mechanisms of, and the variability in, exchanges between the shelves and interior Arctic Ocean. These exchanges are important in establishing the circulation, thermohaline, and potential vorticity structure of the Arctic Ocean. They are also crucial in the maintenance of the Arctic Ocean ice pack and therefore they potentially influence arctic climate. These goals underlie my motivation to:

1. provide an observationally based indication of the variability of the Arctic shelf-basin system, with an emphasis on the Chukchi and Beaufort seas;

2. understand the mechanisms of shelf-basin exchange and contribute to the development of future observational strategies based on this understanding;

3. promote comparison of models to observations by providing patterns and statistics from observations that are useful in model evaluation.

OBJECTIVES

This project is a retrospective study that uses existing data to address:

1. The variability of the shelf sources of the Western Arctic (particularly the Chukchi Sea) and the causes of that variability;

2. The principal mechanisms of exchange across the shelf and slope, with bounds on the rates;

3. The background circulation over the shelf, slope, and adjacent abyssal plain and their relation to shelf-basin exchange;

4. Secondary circulations over the shelf, slope, and adjacent abyssal plain and their variability. What are the sources of the water masses encountered along the slope;

5. Freshwater processing and transport over the shelf.

APPROACH

To address these objectives, I am, in collaboration with Knut Aagaard (U. Washington), analyzing oceanographic time series of velocity, temperature, and salinity gathered from moored instruments

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from the Chukchi and Beaufort seas (primarily) but also from other sites around the Arctic Ocean. Where available and appropriate we will supplement these time series with supplementary hydrographic and chemical tracer data. These data were gathered with support from a range of agencies and programs in the U.S., including NSF, ONR, NOAA, MMS, ANWAP, and OCSEAP. We will capitalize on these measurements by constructing a new synthesis of the circulation and its variability. Our emphasis is on establishing the statistical properties of the measured flows and their temperature and salinity, as well as the dynamics that these statistics imply. We will also make the data sets available via a CD-ROM, on a home page, and/or through National Snow and Ice Data Center.

WORK COMPLETED

We are nearing completion on one manuscript that describes the circulation over the outer Chukchi Sea shelf.

RESULTS

We find that, on average, waters from Bering Strait move northward across the Chukchi shelf and into the Arctic Ocean through Herald Valley (in the western Chukchi Sea), in the channel to the east of Hanna Shoal (in the central Chukchi Sea) and through Barrow Canyon (on the northeast corner of the shelf). Over the outer Chukchi shelf the flow is northeastward, parallel to the isobaths, and opposite to the prevailing wind direction. We conclude that the sea-level slope between the Pacific and Arctic oceans primarily forces the mean flow field. The western and central flow paths advect biologically rich water onto the outer shelf and eventually eastward to the coast of Alaska. They also transport relatively dense shelf waters into the subsurface, eastward flowing boundary current along the Chukchi-Beaufort slope. Bathymetric steering of the mean flow exerts an important thermodynamic control on the shelf ice pack from spring through fall. At this time the warm waters advected along these paths melts the ice and forms large embayments in the ice edge.

While the mean flow is robust, flow variations are large. They are primarily wind-driven and the flow variability is coherent over spatial scales of order 300 km. (By contrast, the spatial coherence scales of the shelf flows along the west coast of the United States are several times smaller.) We also show that seasonal thermohaline processes can exert a significant influence on the shelf circulation. From fall through early spring horizontal density gradients (fronts) form whose strength and sign vary due to the seasonal effects of sea ice formation and advection of different water masses from the southern Chukchi shelf and northern Bering Sea. The length scale of these gradients is poorly resolved but they appear sufficient to force baroclinic currents having magnitudes comparable to the mean flow.

In some winters cold, hypersaline waters form within the extensive coastal polynyas created along the northwest coast of Alaska. Our data suggests that some of this dense water propagates along the bottom into the central Chukchi Sea as eddy-like features with speeds of 0.1 - 0.2 m s^{-1} and length scales of 10-20 km. The data corroborate the theoretical model results of Gawarkiewicz and Chapman (1995) that predict that dense water, formed within polynyas, generates vigorous eddies via baroclinic instability.

We find substantial interannual variability in wintertime thermohaline structure and production of dense water on the Chukchi Sea shelf. In winters that follow extensive fall ice-free conditions, shelf

water column temperatures decrease to the freezing point by early December. However, water temperatures remain above the freezing point well into February in years when heavy ice covers the shelf in early fall. In years when there is extensive development of the coastal polynyas along the coast of Alaska, substantial volumes of hypersaline water (S>34) form in winter. Water with these characteristics is absent from the shelf in years when there is little polynya development.

IMPACT/APPLICATIONS

We have documented that there are three branches along which Bering Strait water is advected across the Chukchi Sea shelf. By contrast Coachman et al (1975) suggested that there were only two branches; one through Herald Valley and the other through Barrow Canyon. Our finding of a third pathway is important because it suggests that much of the outer Chukchi Sea shelf is influenced by advection of waters from Bering Strait. These same waters could have important biological implications for they are generally rich in nutrients and suspended marine-formed carbon.

We hypothesize that because the mean winds and ice drift also oppose the mean flow; there must be a large velocity shear within the upper portion of the water column over the shelf. The existence of these shears (and the nature of the shelf ocean boundary layer) needs to be investigated with an appropriate measurement program. Our findings suggest that bottom-confined eddies are a potentially significant transport mechanism on arctic shelves. These eddies might ventilate the halocline of the Arctic Ocean and they might be precursors to eddies that populate the Canada Basin.

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TRANSITIONS

We have interacted with Glen Gawarkiewicz and David Chapman (both at Woods Hole) in the course of this work. Gawarkiewicz and Chapman are particularly interested in observations pertaining to eddylike features carrying dense water across the shelf.

REFERENCES

Coachman, L.K., Aagaard, K., and Tripp, R.B. 1975: Bering Strait: The Regional Physical Oceanography, University of Washington Press, Seattle, Washington, 172 Pp.

Gawarkiewicz, G. And D. C. Chapman, 1995. A Numerical Study of Dense Water Formation and Transport on a Shallow, Sloping Continental Shelf. J. Geophys. Res., 100, 4489-4508.

PUBLICATIONS

In collaboration with Glen Gawarkiewicz, I have submitted a poster to the ARCSS All Hands Meeting to be held in Virginia Beach in October 1999. The citation is:

Gawarkiewicz, G. and T. Weingartner, Cross-shelf Transport of Dense Water over the Chukchi Shelf: Observations and Process Modelling.

We have submitted an abstract to present a poster at the AGU/ASLO Ocean Sciences Meeting to be held in San Antonio in January 2000. The citation is:

Weingartner, T., K. Aagaard, K. Shimada, D. Cavalieri, and A. Roach, Circulation on the central Chukchi Sea Shelf.